Before the

Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
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IN RE: DELETE, DELETE, DELETE	)	GN Docket No. 25-133
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COMMENTS OF mmWAVE COALITION

The mmWave Coalition, "mmWC", is pleased to submit its comments to this FCC Public Notice/PN "to unleash prosperity through deregulation and ensure that they are efficiently delivering great results for the American people." mmWC fully supports this goal.

mmWC is a group of innovative companies united in the objective of removing regulatory barriers to technologies using frequencies ranging from 95 GHz to 275 GHz. The 16 industrial and academic members of the Coalition are listed in Attachment I.

The PN states "Specifically, we are seeking public input on identifying FCC rules for the purpose of alleviating unnecessary regulatory burdens." In many cases throughout the US government deregulation generally involves deleting rules. However, in the special case of innovative radio technologies in bands that presently lack "services rules" enabling the sale of use of new radio technology under the terms of § 302a(b) of the Communications Act of 1934, "the Act" as amended, or the use of a transmitter under either the terms of § 301, in the case of

licensed systems, or under §§ 15.201,258[1] of the Commission's Rules, in the case of unlicensed systems, there is an implicit prohibition of the new technology in such a band and the only way to remove this regulatory barrier is actually creating a new rule.

Here are 2 historic examples:

• No FCC regulatee could have used a transmitter in 59-64 GHz, except for the limited case of an experimental license, until the Commission adopted the initial version of § 15.255 in 1998.[2]

• Similarly, no nonexperimental access was allowed to 71-76 GHz and 81-86 GHz bands until the Commission adopted the initial version of §§ 101.1501,1528 in 2004.[3][4]

So, in this special case of innovative spectrum technology in bands without previous FCC service rules, "alleviating unnecessary regulatory burdens*" actually necessitates adopting new rules* that allow routine access to additional spectrum in transparent ways that achieve the goals of § 7(a)[5] and § 303(g) of the Act[6], notwithstanding the multiple use of "delete" in the name of this proceeding.

[1] 47 CFR §§ 15.201,258
[2] 63 FR 42279
[3] 69 FR 33261
[4] It should be noted that the rules in § 15.255 and §§ 101.1501,1528 permitted new used that had been implicitly forbidden and had no impact on any regulation in any other band, so while these were "new rules" they were *actually* intrinsically deregulatory. While the impact of these rules is not well understood by the general public, they were later widely copied by FCC's national counterparts in other countries and a wide variety of equipment is now commercially available and used around the world as a result of FCC's visionary actions in these 2 examples.
[5] "It shall be the policy of the United States to encourage the provision of new technologies and services to the public." 47 USC §157(a)
[6] "generally encourage the larger and more effective use of radio in the public interest" 47 USC §303(g)

Capital formation for privately-funded R&D on radio technology products and services in bands without transparent rules and policies is extremely difficult due to the associated regulatory risk[7]. All technical R&D has risks associated with it since there is always uncertainty about whether it will result in products or services that will perform a practicable function at a reasonable price to users that are willing to adopt it. But in the highly regulated area of spectrum technology there are *also* major uncertainties concerning whether market access will be possible in bands without current rules if FCC does not amend in a timely way its rules to permit such access. The revolutionary introductions of Wi-Fi in 1999 and the iPhone in 2007 may well be due to the fact that these new radio products only needed routine timely staff approvals under applicatory deregulatory rules and did not need *any* FCC rule changes. Historically FCC has taken years to reach to petitions for new band access, despite the generally deregulation of spectrum over the past several decades. FCC's pioneering decision in the Spectrum Horizons proceeding, Docket 18-21 to create the Spectrum Horizons Experimental Radio Licenses"/ 'SHERL"[8] was an attempt to ameliorate this situation,

The discussion below considers 3 barriers to innovation of new products that mmWC hopes the Commission will address. First, that ambiguity about the current US position on WRC-2000 Resolution 731, a policy first proposed by the US in its input to that conference, shown in Attachment 2, that has now become very contentious in many domestic and international spectrum policy issues above 100 GHz, that should be addressed by the leadership of FCC, NTIA and State Department. Second, mmWC is concerned that recent experimental licensing actions resulting from FCC/NTIA coordination with apparent insufficient oversight by FCC and NTIA leadership that may vitiate the laudable goals of SHERL program adopted by

[7] https://corporatefinanceinstitute.com/resources/career-map/sell-side/risk-management/regulatory-risk/
[8] 47 CFR § 5.701,705

FCC with apparent interagency coordination with NTIA under the terms of the agencies' MOU[9] and may be inconsistent with the goals of the leadership of both FCC and NTIA. And third, that the present lack of transparent rules for Terahertz Spectroscopy, a noncommunications application that is useful in several applications including real time quality control in industrial manufacturing. This is particularly ironic in that a historic goal of the Department of Commerce has been the efficiency and competitiveness of US manufacturing and this may be a historically rare instance of a possible conflict between a major Commerce Department goal and the goals of one or more IRAC member agencies.[10]

FCC and NTIA, in Consultation with State Department, Should Clarify the National Understanding of WRC-2000 Resolution 731 as Amended

Most of the exclusive passive band allocations above 95 GHz included today in ITU Radio Regulation 5.340 and US Allocation Table footnote US246[11] were made at WRC-2000 as result of proposals from the US[12] and parallel proposals from Europe's CEPT. Both the US and CEPT proposals indicated uncertainty about whether the preamble of 5.340, originally drafted for lower bands with very different propagation characteristics, was appropriate above 95 GHz and both proposals included a draft on future ITU-R studies on the possibility of sharing the exclusive passive bands above 95 GHz. WRC-2000 adopted Resolution 731/"Res. 731" based in part of the US and CEPT inputs. Res. 731 has been amended twice and the current terms of the two key sections for sharing above 95 GHz are:

> • *Invites 1*:
> Invites the ITU Radiocommunication Sector to continue its studies to determine if and under what conditions sharing is possible between active and passive services in the frequency bands above

[9] https://www.ntia.gov/sites/default/files/publications/ntia-fcc-spectrum_mou-8.2022.pdf
[10] It should be noted that the longstanding provisions of § 1.3.2 of NTIA's Manual of Regulations for Federal Radiofrequency Spectrum Management provide that "The basic role of representatives appointed to serve on the IRAC is to function, when in Committee, in the interest of the United States as a whole" (https://www.ntia.gov/sites/default/files/2023-11/1_2021_edition_rev_2023.pdf)
[11] 100-102 GHz, 109.5-111.8 GHz, 114.25-116 GHz, 148.5-151.5 GHz, 164-167 GHz, 182-185 GHz, 190-191.8 GHz, 200-209 GHz, 226-231.5 GHz, and 250-252 GHz
[12] *See* Attachment 2

71 GHz, such as, but not limited to, 116-122.25 GHz, 174.8-182 GHz, 185-190 GHz and 235-238 GHz;[13]

• *Invites 5*:
Invites the ITU Radiocommunication Sector to take into account the principles of burden-sharing to the extent practicable in their studies;

It is clear that the World Meteorological Organization/"WMO" adopted a position for WRC-23 stating

> "With regards to Resolution **731 (Rev. WRC-19)**, WMO supports a revision of this WRC Resolution under agenda item 4 to clarify that in-band sharing studies cannot be performed in bands covered by RR No. **5.340**."[14]

It is also clear WMO did **not** get the specific language it intended adopted at WRC-23. The resulting wording of *Invites 1, "*continue its studies to determine if and under what conditions sharing is possible between active and passive services in the frequency bands above 71 GHz, such as, **but not limited to**, …." (emphasis added) does not forbid consideration of sharing in any specific passive bands above 71 GHz. While it is clear that federal agencies with passive satellite uses in this band believe the current text of *Invites 1* forbid any consideration of sharing 5.340 bands and that certain NTIA staffers agree with them, it is not clear what the national viewpoint of the US is on this issue, which is a point that requires consultation between FCC, NTIA and State Department. There is parallel uncertainty about *Invites 5* on "burden sharing" although it is interesting to note the specific wording of both *Invites* 5 and a second mention of burden sharing in Res. 731[15] come verbatim from the US input to WRC-23.

Suggestion for FCC:

mmWC understands that the spectrum policy of the US is not forever bound to a policy developed in preparation for an ITU conference a quarter century ago. But there is a major

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[13] https://www.itu.int/dms_pub/itu-r/opb/act/R-ACT-WRC.16-2024-PDF-E.pdf at p. 635

[14] https://meetings.wmo.int/Cg-19/English/2.%20PROVISIONAL%20REPORT%20(Approved%20documents)/Cg-19-d04-2(10)-WMO-POSITION-WRC-23-AGENDA-approved_en.docx (Note that under ITU WRC procedures for "agenda item 4" WMO could bring up a specific issue that was not on the published agenda and which has not be addressed by the US in its WRC-23 preparation)

[15]
b) *Recognizing b*
"that, to the extent practicable, the burden of sharing among active and passive services should be equitably distributed among the services to which allocations are made"

transparency issue that discourages capital formation for upper spectrum R&D if the private sector doesn't understand what the US position is on these 2 issues and if different agencies have different views on what today's text of Res. 731 means. Thus we ask for FCC to consult with NTIA and State Department on a clear statement of how our country interprets *Invites 1* and *Invites 5*.

Furthermore, mmWC recommends that sharing studies in progress be supported with explicit work in passive bands defined in Radio Regulations 5.340 and US246 to determine if a quarter of century of technical progress has rendered the previously stated rules antiquated and in need of amendment. If studies in progress are not sufficient, mmWC recommends new studies, either privately or publicly funded, to the same point.

Recent FCC Actions on Experimental Licenses Processing May Vitiate Its Pioneering Spectrum Horizons Experimental License Policy

The Docket 18-21 *R&*O begins with this bold goal statement,

> "Innovators continue to push technological boundaries in wireless communications. Frequency bands once thought of as unusable are now well within the range of modern communications systems. With this *First Report and Order*, we take steps to provide new opportunities for innovators and experimenters to push those boundaries even further, and to develop new equipment and applications for spectrum between 95 GHz and 3 THz.[16]

This was achieved with the novel combination of creating 4 modest sized unlicensed bands[17] and creating an innovative new class of "Spectrum Horizons Experimental Radio Licenses"/ 'SHERL"[18]. The Commission went on to state

> "Specifically, the Spectrum Horizons License will be available for experiments and demonstrations of equipment designed to operate exclusively on any frequency above 95 GHz … Applicants for Spectrum Horizons Licenses *may request authorization on any frequency* within the 95 GHz to 3 THz frequency range. *We will not, by rule, preclude the use of any specific frequencies.* By adopting this expansive approach to experimental licensing for these bands, we seek to foster an environment where innovators can develop new products and applications absent unnecessary limitations."[19]

[16] Docket 18-21*, 1st R&O* at para.1
[17] 47 CFR § 15.258
[18] 47 CFR § 5.701,705
[19] Docket 18-21*, 1st R&O* at para. 9,11

The private sector can not fund R&D on spectrum above 95 GHz that is overlapping or adjacent to passive bands unless there is **basic transparency** on how the Commission will deal with SHERL applications. Publicly available material on FCC/NTIA coordination on >95 GHz classic experimental applications and resulting FCC actions create much doubt as to how FCC would deal with a SHERL application which offer the more generous terms of both 10 year duration and the ability to market equipment to other users which can operate such equipment under the SHERL.

mmWC, in its comments in Docket 18-21 expressed concern about how normal FCC/NTIA coordination would be effective in this case. The Commission acknowledged by summarizing them these concerns as:

> "that the current IRAC coordination process effectively gives a government agency the ability to veto an experimental application regardless of whether there is any potential for real-world interference to government spectrum users."[20]

The Commission further states in the Docket 18-21 *1st R&O*

> "With respect to showing a sufficient methodology for preventing harmful interference, we note that parties are always free to seek guidance from the FCC and/or discuss their specific proposals with incumbent operators prior to filing an application"[21]

Unfortunately, the past 5 years of experimental license actions seems to imply that the "IRAC coordination process" for *any type* of experimental licenses in or near a passive band, including SHERL, may be close to what mmWC's concerns were in its above quoted comments.

These well intended suggestions in fn.29 have just not been successful. Attachment 4 shows publicly available data from recent FCC actions on experimental licensing above 95 GHz.

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[20] *Ibid.* at fn 29
[21] *Ibid.*

Although these actions do not involve SHERL applications, the fact that much more limited conventional Part 5 licenses have consistently faced such limitations is very chilling due to large regulatory risk to anyone planning to invest in the R&D for an SHERL license.

Guidance from FCC staff to date has indicated an unwillingness to address the disparity between results of NTIA coordination under the FCC/NTIA MOU and the policies the Commission have adopted with respect to experimental licenses in passive bands. Further attempts to pursue "an opportunity for dialogue between affected (federal agency) parties and applicants" have always resulted in statements from such agencies that Radio Regulations 5.340 and US246 categorically forbid any such transmissions under any circumstances and have been silent on the applicability of the Docket 18-21 *1st R&O* as well as the terms of § 5.85(a) as if the "affected parties"/federal agencies do not recognize the legitimacy of either FCC action.

Suggestion for FCC:

This situation does <u>not</u> require either the deletion of any rule or the creation of a new rule. mmWC believes that since most experimental licensing processing at lower bands does not have such problems because there are well established policies and precedents, senior leadership at FCC and NTIA have not been aware of problems in the special case of experimental licensing in 95-275 GHz. mmWC urges FCC leadership to discuss these problems with their counterparts at NTIA and see how the agencies can cooperate together more effectively to have experimental license processing be consistent with FCC rules and policies or fine tune FCC policies into terms that can FCC/NTIA consensus in the jurisdiction of both agencies.

Terahertz Spectroscopy Needs Transparent Technical Rules to Remove Barriers to R&D and Encourage its Use in Manufacturing to Increase US Competitiveness

Terahertz Spectroscopy "THzS", called RDI-S ("RadioDetermination Industrial - Shielded") in Europe is not a communications technology, but an innovative use of extremely broadband spectrum above 60 GHz at very short distances, typically less than a few cm or one meter, usually at indoor locations to measure the spectral mmWave fingerprint of objects. It is very helpful in manufacturing operations to determine the thickness of coatings or the integrity of products such as plywood, paper, ceramics, or plastics and can do so on a production line as objects are moving so that real time adjustments can be made to assure high levels of quality control and prevent manufacture of object that don't meet the intended standards. Attachment 3 describes how the industrial application of this technology was developed with NASA funding to the company that is now named Luna which

> "improved the portability and capabilities of their systems through Small Business Innovation Research (SBIR) agreements with Langley Research Center to provide terahertz imaging capabilities for inspecting the space shuttle external tanks and orbiters."[22]

In comments to Docket 18-21 Luna stated

> "TeraMetrix's T-Ray 5000 series of "T-Gauge" instrumentation is used for industrial on-line factory process monitoring and control by measuring multi-layer thickness of extruded plastics; multi-layer thicknesses of paints (including wet paint); basis weight; density; delamination and moisture. TeraMetrix's time domain terahertz gauges are deployed worldwide in factories that make tires, rubber, building products, paper, plastic pipe, coated steel pipe, blow molded bottles, aircraft coatings, fuel tanks, and many other products. As a non destructive, imaging device, TeraMetrix imagers are/have been used to image the Space Shuttle external tank, the Space Shuttle thermal protection system, Orion spacecraft thermal protection system, military aircraft coatings, military ship coatings, radomes, food, pharmaceuticals, and other products."[23]

In the Docket 18-21 NPRM, the Commission stated

> We are aware of interest in using the spectrum above 95 GHz for devices that use terahertz spectroscopy to analyze material properties and for imaging applications, which could possibly be considered ISM applications. While the Office of Engineering and Technology currently evaluates applications for devices that use the frequencies above 95 GHz on a case-by-case basis, we note that it has found that some equipment used to detect the presence of powders,

[22] https://spinoff.nasa.gov/Spinoff2010/ps_8.html
[23] *Comments of TeraMetrix*, *a Division of Luna Innovations, Inc.,* Docket 8-21, May 2, 2018 (https://www.fcc.gov/ecfs/document/1051556006218/1)

> solids and liquids inside sealed parcels and envelopes to be ISM equipment subject to Part 18 of the rules. We seek comment on whether we should establish a more certain regulatory approach for devices that use the frequencies above 95 GHz.[24]

mmWC's comments in Docket 18-21 addressed this issue:

> The current approach of OET evaluating equipment that uses the above-95 GHz frequencies on a case-by-case basis does not provide the regulatory certainty needed for investment in new ISM technology development or for buyers of to invest in such expensive equipment. The case-by-case evaluation also deters the efficiencies that result from a more predictable regulatory environment including the development of components that can be used in different types of ISM equipment. One example of a new technology that would benefit from greater regulatory certainty is Terahertz Spectroscopy, which the Notice identifies as a technology that is well-suited for the above-95 GHz frequencies given the shorter wavelengths and that has garnered interest for these frequencies.[25]

While the Docket 18-21 *Report & Order* mentioned THzS in passing in 2 places[26], it did not adopt any specific rules, leaving in place the "evaluat(ion of) applications for devices that use the frequencies above 95 GHz on a case-by-case basis" mentioned in the *NPRM.* As a result, Luna is effectively grandfathered in with their Part 18 approval, the details of which are even off the public record under the terms of the Supplier's Declaration of Conformity procedure in § 18.203(a).[27] mmWC urges the Commission to review the concerns we raised in our above quotes Comments in Docket 18-21 and act in a timely way to propose explicit and transparent standards for THzS. Recent action in Europe both complements this request and highlights the urgency for it. In 2022 CEPT's European Communications Committee adopted clear and explicit emission limits for THzS/RDI-S in ECC Decision (22)03[28].

So European test equipment companies have regulatory certainty to develop this equipment and European factories have a clear pass to use such equipment with no regulatory

[24] *NPRM*, Docket 18-21, February 28, 2018, at para.61
[25] *Comments of mmWC*, Docket 18-21, May 2, 2018,at p.12
[26] *R&O*, Docket 18-21, March 21, 2019, at para. 3 and Statement of Comm. Starks
[27] 47 CFR § 18.203(a)
[28] CEPT/ECC, Technical characteristics, exemption from individual licensing and free circulation and use of specific radiodetermination applications in the frequency range116-260 GHz, ECC Decision (22)03, Adopted 8 November 2022, amended 8 March 2024 (https://docdb.cept.org/download/4437)

uncertainty. In the US market, Luna now has a *de facto* legal monopoly and any potential market entrant would have develop its equipment with significant regulatory risks with respect to its approval. Indeed, if such regulatory approvals are viewed as being subject to FCC/NTIA coordination under their MOU[29], recent actions discussed below on experimental licensing actions on THzS prototypes that suggest NTIA objections to this technology further raise concerns of regulatory uncertainty and lack of transparency. This is particularly puzzling since both in this Administration and in previous ones for several decades, promotion of efficient manufacturing has been a major goal of the Department of Commerce and the main use of THzS has been in improving efficient manufacturing by enabling real time quality control for any manufacturing technologies.

Rule Change Proposal:

mmWC urges the Commission to propose Part 18 rules for THzS indoor use in manufacturing facilities using the CEPT/ECC emission limits in Attachment 5 as an initial proposal. At this time there is no significant legitimate use of this technology in *any* outdoor applications which would raise complex issues of possible interference to passive environmental satellites in bands protected by allocation footnote US246. The Commission might provide for such hypothetical outdoor use by using the experimental license approach with NTIA coordination that it has used for authorizing GPS reradiators[30] which also are useful devices in some applications but pose an analogous potentially hazardous interference risk (in this case to civil and military GPS receivers) unless the transmissions are very carefully controlled. Good

[29] Memorandum of Understanding Between the FCC and NTIA, August 2, 2022 (https://docs.fcc.gov/public/attachments/DOC-385867A1.pdf)
[30] https://www.gps-repeaters.com/licensing/gps-repeaters-current-legislation-usa/

spectrum policy does not eliminate all interference risks, but has justified restrictions to prevent them in situations that are safety related.

The main uses for THzS are for industrial manufacturing and R&D uses. Passive spectrum users above 100 GHz may be concerned that in the long term low cost versions of THzS equipment *might* proliferate in outdoor uses or in poorly shielded residential applications and that cumulative use of such devices would adversely impact critical uses of passive spectrum such as collecting data for severe storm warning. Thi sis a hypothetical concern as this equipment is presently very expensive. Nevertheless, this concern could be addressed in an FCC NPRM by building on the precedent of the Class A/Class B dichotomy of emission limits in Subpart B of Part 15[31] for "digital devices", *e.g*. personal computers. FCC could propose transparent THzS emission limit based on the CEPT/ECC policy limits for industrial and R&D uses and propose much lower limits for all other applications - with special cases being handled by Part 5 experimental licenses (based on the GPS reradiator precedent) as in our proposal for handling all outdoor uses of THzS that is mentioned above.

[31] 47 CFR § 15.101,109

Conclusions

mmWC has participated in past FCC and NTIA policy deliberations on issues related to spectrum above 95 GHz and appreciates this opportunity to address this proceeding commendable goals to "to unleash prosperity through deregulation and ensure that they are efficiently delivering great results for the American people." In the special cases discussed here the key to such unleashing is not "deleting" regulations but rather either adopting carefully crafted new ones that further the unleashing goals consistent with other legitimate national spectrum policy goals and better regulatory transparency by FCC on the implementation of spectrum policies that it has adopted through rulemakings including coordination with NTIA. mmWC looks forward to participating with FCC staff and leadership on these vital issues.

/s/

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ATTACHMENT 1

Members of mmWave Coalition

American Certification Body, Inc.

Azbil North America Research and Development, Inc.

Brown University

indie Semiconductor

Keysight Technologies

Nokia Corporation

Northeastern University

NXP Semiconductors

NYU WIRELESS

Oklahoma State University

Qualcomm

TCB Council

The University of Arizona

2π-LABS GmbH

VEGA Americas

Virginia Diodes, Inc.

VUBIQ Network

ATTACHMENT 2: US Input to WRC-2000 that resulted in Resolution 731

ADD USA/12/127

DRAFT RESOLUTION XXX (WRC-2000)

Consideration by a future world radiocommunication conference of issues dealing with sharing between passive and active services 71 GHz

The World Radiocommunication Conference (Istanbul, 2000),

considering

a) that the changes made to the Table of Frequency Allocations by WRC-2000 in bands above 71 GHz were based on the requirements known at the time of the Conference;

b) that the passive service spectrum requirements above 71 GHz are based on physical phenomenon and therefore are well known. These requirements are reflected in the changes made to the Table of Frequency Allocations by WRC-2000;

c) that several bands above 71 GHz are already used by EESS (passive) and SR (passive) because they are unique bands to measure specific atmospheric parameters;

d) that currently there is only limited knowledge of requirements and implementation plans for the active services to operate in bands above 71 GHz;

e) that in the past, technological developments have led to viable communication systems operating at increasingly higher frequencies and this can be expected to continue so as to make communication technology available in the future for the frequency bands above 71 GHz;

f) that in the future, there should be accommodation of alternative spectrum needs of the active and passive services when the new technologies become available;

g) that, following the revisions to the Table of Frequency Allocations by WRC-2000, sharing studies may be required for services in some bands above 71 GHz;

h) that interference criteria for passive sensors have been developed and are given in ITU-R SA.1029-1;

i) that sharing criteria for active and passive services in bands above 71 GHz have not yet fully developed within the ITU-R;

j) that, in order to ensure the protection of passive services above 71 GHz, WRC-2000 avoided co-allocations of active and passive services to prevent potential sharing problems,

recognizing

that to the extent practicable, the burden of sharing among active and passive services should be equitably distributed amongst the allocated services,

invites ITU-R

1 to continue its studies to determine if sharing is possible between active and passive services in the bands above 71 GHz;

2 to take into account the principles of burden sharing to the extent practicable in their studies;

3 complete the necessary studies, as soon as the technical characteristics of the active services in these bands are known;

4 develop recommendations specifying sharing criteria for those bands where sharing is feasible,

resolves

that a future competent conference should consider the results of ITU-R studies with a view to revising as appropriate the Radio Regulations in order to accommodate the emerging requirements of the active services taking into account the requirements of the passive services, in bands above 71 GHz,

instructs the Secretary-General

to bring this Resolution to the attention of the international and regional organizations concerned.

ATTACHMENT 3

NASA Technology Transfer Program Discussion of Terahertz Imaging/Terahertz Spectroscopy

Public Safety

Terahertz Tools Advance Imaging for Security, Industry

Originally published in 2010

Originating Technology/NASA Contribution

On January 16, 2003, the Space Shuttle Columbia launched on mission STS-107. At T plus 82 seconds, with the orbiter rocketing upwards at 1,870 miles per hour, a briefcase-sized chunk of insulating foam broke off from the external fuel tank and struck Columbia's left wing. During reentry on February 1, hot gasses entered the wing through the damaged area of the orbiter's thermal protection system, causing devastating structural failure that led to the destruction of Columbia and the deaths of the seven crew members onboard.

After the Columbia disaster, NASA grounded the space shuttles for more than a year as it worked on new safety protocols to ensure that such a tragedy would not happen again. As part of the preparations for the Return to Flight mission, the Agency required a method for detecting potentially hazardous defects in the external tank's sprayed-on insulating foam prior to launch.

Partnership

NASA Langley Research Center scientists suspected that a new imaging technology called terahertz imaging had the potential to accurately find flaws in the foam on the external tank. Terahertz radiation—lying between microwaves and far infrared on the electromagnetic spectrum—offers imaging capabilities similar to X-rays, but unlike X-rays, terahertz radiation is non-ionizing and thus safe for frequent human use. Terahertz wavelengths can be used to see through many

materials and reveal defects like cracks, voids, and density variations. They can be used to image or as an anomaly detector, or both at the same time.

Picometrix, of Ann Arbor, Michigan, was at the forefront of the emerging field of terahertz imaging. In 2000, Picometrix introduced the world's first commercial terahertz system, the T-Ray 2000. The T-Ray 2000 was based upon the company's patented fiber coupling system, but was a non-integrated, workbench-mounted system, which rendered it fine for the research market but impractical for NASA's manufacturing quality control needs. Langley researchers asked the company via Small Business Innovation Research (SBIR) agreements to quickly redesign the terahertz systems to be more integrated and deployable into a manufacturing environment.

Based on the success of that new prototype system, the company was next asked to deliver a more compact, self-contained terahertz system, the T-Ray QA-1000, and NASA purchased five of the systems for inspecting the external fuel tanks as they were being manufactured by Lockheed Martin. The QA-1000's long, optical fiber umbilicals enabled the system's terahertz sensors to scan the tank from top to bottom. The systems were deployed at NASA's Michoud Assembly Facility and at Marshall Space Flight Center. Langley's original unit was later retrofitted with a similar higher speed delay stage that was also capable of imaging thicker foam.

"This was significant. In addition to the company's patented fiber coupling system that makes Picometrix systems unique, they can also inspect thicker material at substantially higher speed with our T-Ray systems versus others terahertz systems," says Irl Duling III, company director of terahertz business development.

Picometrix became a wholly owned subsidiary of Advanced Photonix Inc. (API), also of Ann Arbor, Michigan, in 2005. The company's terahertz systems—including its latest, highly compact and rugged T-Ray 4000 systems—were later adopted by Kennedy Space Center as a diagnostic tool for scanning the orbiter's thermal tiles for the remaining shuttle flights. The systems offered an effective way of not only

inspecting the tiles for hidden damage, but also of precisely locating components underneath the tiles that were in need of attention—without the costly removal and replacement of extra tiles which often happened before the use of the T-Ray 4000.

"With this technology, NASA could scan and see the precise location of wires and antennas and remove only the necessary tiles," says Picometrix engineer Greg Stuk. "In one example, it saved the Agency hundreds of thousands of dollars."

Product Outcome

The imaging capabilities of terahertz make it useful for a wide range of applications. It can be employed as a safer, more precise security measure than X-rays in airports and other buildings, revealing concealed weapons and theof packages. Since numerous materials have specific spectral signatures revealed by terahertz radiation, it provides spectroscopic and other unique identification information useful for chemical analysis, pharmaceuticals, and explosives detection. Not only can terahertz see through an opaque pill bottle, for example, it can also reveal the chemical makeup of the pills inside. It can also provide high-resolution imaging down to 200 microns. The industrial possibilities of terahertz range from determining the uniformity of coating thickness to detecting hidden defects to ensure product quality.

The company now offers the T-Ray 4000 Time-Domain Terahertz System commercially. Featuring its patented fiber-pigtailed transmitter and receiver modules, the T-Ray 4000 is designed for both the research laboratory and the industrial setting. The T-Ray 4000 takes the next step beyond the NASA-inspired T-Ray QA-1000 system. While the QA-1000 is about the size of a small refrigerator, the T-Ray 4000 is an easily portable, rugged, briefcase-size system weighing only about 50 pounds. As a time-domain terahertz system, the T-Ray 4000 generates high-speed picosecond (one-trillionth of a second) duration terahertz pulses for scanned spectroscopy or imaging. These qualities, along with the patented fiber-coupled sensor heads that can scan objects of almost any size, make the T-Ray 4000 an easy-to-use tool for terahertz applications beyond the laboratory—though it is

useful there as well.

"As far as having a product that you can deploy onto a manufacturing floor, this is the first of its kind," says Duling. He credits the company's NASA work with helping drive this industry-leading advancement.

"The rest of the industry is trying to figure out how to generate terahertz, how to detect it, how to build a complete system that can be fielded," he says. "In part through NASA's motivation, we've been able to complete that full-system integration and turn it into something we can take out into the field and use as a tool."

"Our systems' features now allow terahertz to access the most obscure places," says Steve Williamson, the company's chief technology officer. "It's a powerful benefit to our customers."

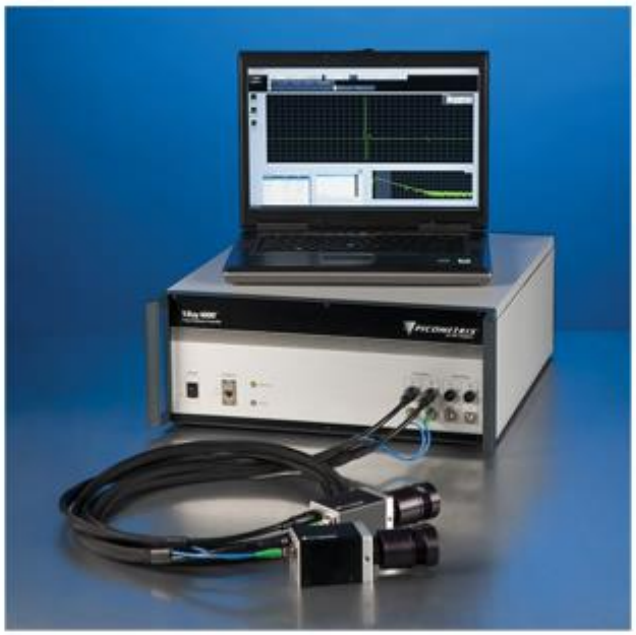
API's terahertz systems can be used for thickness measurements of roofing material, paper and paper coatings, and coatings on films. They also can be employed for pharmaceutical applications like aseptic packaging and tablet production. Art conservationists from prestigious institutions like the Uffizi Gallery and the Louvre have used API systems to date paintings, look for pigment concentrations, and reveal frescos on walls that have been painted over. The technology has been even applied to examine the structure of pagodas in Japan, providing guidance for renovations. These are only a few examples of the benefits of this still developing field, says API CEO Richard Kurtz.

"Terahertz has huge market potential. We estimate there are over $200 million in opportunities for our terahertz systems over the next 7 years," he says. To help API stay at the forefront of the terahertz industry, the company is continuing work with NASA through SBIR contracts with Glenn Research Center. The goal of this partnership is a computed axial tomography time-domain terahertz system capable of creating three-dimensional images.

"There has been great collaboration between API and NASA," says Williamson. "NASA has helped us push the envelope."

T-Ray®, T-Ray 2000®, and T-Ray 4000® are registered trademarks of Advanced Photonix Inc.

Picometrix, a wholly owned subsidiary of Advanced Photonix Inc. (API), of Ann Arbor, Michigan, invented the world's first commercial terahertz system. The company improved the portability and capabilities of their systems through Small Business Innovation Research (SBIR) agreements with Langley Research Center to provide terahertz imaging capabilities for inspecting the space shuttle external tanks and orbiters. Now API's systems make use of the unique imaging capacity of terahertz radiation on manufacturing floors, for thickness measurements of coatings, pharmaceutical tablet production, and even art conservation.



The T-Ray 4000 Time-Domain Terahertz System, capable of generating high-speed terahertz pulses and equipped with fiber-coupled sensor heads, is a versatile and user-friendly instrument for use in the laboratory and in real-world applications.

The space shuttle's external tank is coated in insulating foam that must be checked for defects. To accomplish this, NASA turned to the developing field of terahertz imaging.

ATTACHMENT 4

Data from FCC's Experimental Licensing System on Experimental Licensing Actions on 95-275 GHz Applications

• File No. 0859-EX-CN-2021

"You are advised that the Commission is unable to grant your application for the facilities requested. The application is dismissed because NTIA and NASA objected to authorize Brown University the use of equipment for long term operation regard to the frequency band 97.5-103 GHz with emission designator 2G00K10. It is recommended Brown University should ensure that the operational use of the equipment be conducted in appropriately allocated frequency bands that are authorized to transmit."

Comment – No indication that the information in the application's Supplemental Statement on steps taken to prevent harmful interference was even considered by FCC, NTIA or NASA. Focus appears to be on "appropriately allocated frequency bands that are authorized to transmit" and thus ignores the statement in Docket 18-21 *1st R&O* as well as the terms of § 5.85(a) -- both of which were presumably were coordinated with NTIA before adoption by FCC

• File No. 1218-EX-ST-2024

"You are advised that the Commission is unable to grant your application for the facilities requested. This STA has been dismissed due to NTIA objection. Please consult the NASA Spectrum Planning and Policy Office prior to any STA request in this band."

Comment – No indication that the information in the application's Supplemental Statement on steps taken to prevent harmful interference was even considered. No indication of the reason for NTIA's "objection". Referral to "NASA Spectrum Planning and Policy Office" (without even an indication of how to contact them). Applicant subsequently contacted a responsible individual in this group through NASA's IRAC representative. Discussion with this individual only addressed NASA's total objection to any transmission in a band subject to ITU Radio Regulation 5.340 or US allocation footnote US246 in apparent contradiction with terms of Docket 18-21 *1st R&O* as well as the terms of § 5.85(a). FCC staff and NTIA staff both indicated that NASA's objection necessitated dismissing the application and did not want to discuss the adequacy of the technical steps the applicant proposed to take to prevent harmful interference to passive satellites.

• File No. 0352-EX-ST-2023

"Quad Plus should also be aware that current US regulations do permit the operational use of the requested facilities, and Quad Plus is cautioned that long-term or operational use of this system is not possible. This STA expires 31 August 2023 and Quad Plus shall have no expectations that future requests for modification or extension of this authorization will be approved."

Comment – This application was for "a well shielded indoor setup as a replacement for THz TDS sensing devices." At the frequencies involved her buildings are essentially opaque to radio

transmissions which is why the above cited European decision allows commercial indoor use of this technology subject to quantitative emission limits. This rejection is also puzzling since FCC is aware of and permits the marketing and use of Luna THzS system that was developed under NASA contract funding. Such complete rejection seriously complicates capital formation for R&D and improvement of manufacturing processes using this technology.

• File No. 0592-EX-ST-2023

"The 148.5-151.5 GHz and 164.0-167.0 GHz frequency bands shall be excluded from operation in accordance with Footnotes US246 and 5.340."

Comment – This application's supplemental statement included "Over the course of 180 days, Vubiq's experimental operation will be combined inside a building at each site with sufficient shielding to protect against generating interference and to extend the signal no more than 1 meter to the test target." There is no indicating here that FCC, NTIA or any IRAC member found the technical aspects of this insufficient to prevent harmful interference

While the cite "Footnotes US246 and 5.340" both address these frequency bands, the provisions of the Docket 18-21 *1st R&O* as well as the terms of § 5.85(a) explicitly allow consideration of the use of these bands for experimental licenses *if* it can be demonstrated that such experimental use does not cause harmful interference.

• File No. 1965-EX-ST-2023

"The 148.5-151.5 GHz and 164.0-167.0 GHz frequency bands shall be excluded from operation in accordance with Footnotes US246 and 5.340….Quad Plus should also be aware that current US regulations do not permit the operational use of the requested frequencies, and Quad Plus is cautioned that long-term use of this system is not possible. Quad Plus shall have no expectations that future requests for modification or extension of this authorization will be approved. All operations shall be conducted in a highly shielded indoor environment that does not contain non-RF shielded windows."

Comment – Given the requirement, first proposed by the applicant, that "all operations shall be conducted in a highly shielded indoor environment" it is not clear why it was necessary to delete the 2 specified bands unless the party requiring this deletion was either unaware of or opposed to the related provisions of the Docket 18-21 *1st R&O* as well as the terms of § 5.85(a).

ATTACHMENT 5

ECC Decision (22)03 (amended 8 March 2024) Standards for RDI-S (THzS)

Table 10: Technical requirements for RDI-S devices in the designated band 116-260 GHz

Frequency range	Maximum duty cycle	Maximum mean e.i.r.p. spectral density (Note 2)	Maximum peak e.i.r.p. (Note 4)	Unwanted emission limits (Note 1)
	A	B	C	D
116-122.5 GHz	100%	-5 dBm/MHz	45 dBm	
122.5-123 GHz	100%	-5 dBm/MHz	45 dBm	
123-130 GHz	100%	+10 dBm/MHz	60 dBm	
130-134 GHz	100%	-5 dBm/MHz	45 dBm	
134-141 GHz	100%	+10 dBm/MHz	60 dBm	
141-148.5 GHz	100%	-5 dBm/MHz	45 dBm	
148.5-151.5 GHz (Note 3)	100%	-15 dBm/MHz	35 dBm	
151.5-158.5 GHz	100%	-5 dBm/MHz	45 dBm	
158.5-164 GHz	100%	-5 dBm/MHz	45 dBm	
164-167 GHz (Note 3)	100%	-15 dBm/MHz	35 dBm	
167-174.5 GHz	100%	-5 dBm/MHz	45 dBm	-15 dBm/MHz max. mean e.i.r.p. spectral density (Note 2) and 35 dBm max. peak e.i.r.p. (Note 4)
174.5-174.8 GHz	100%	-5 dBm/MHz	45 dBm	
174.8-182 GHz	100%	+10 dBm/MHz	60 dBm	
182-185 GHz (Note 3)	100%	-15 dBm/MHz	35 dBm	
185-190 GHz	100%	-5 dBm/MHz	45 dBm	
190-191.8 GHz (Note 3)	100%	-15 dBm/MHz	35 dBm	
191.8-200 GHz	100%	-5 dBm/MHz	45 dBm	
200-209 GHz (Note 3)	100%	-15 dBm/MHz	35 dBm	
209-226 GHz	100%	-5 dBm/MHz	45 dBm	
226-231.5 GHz (Note 3)	100%	-15 dBm/MHz	35 dBm	
231.5-235 GHz	100%	-5 dBm/MHz	45 dBm	
235-238 GHz	100%	-5 dBm/MHz	45 dBm	
238-241 GHz	100%	-5 dBm/MHz	45 dBm	
241-244 GHz	100%	-5 dBm/MHz	45 dBm	
244-246 GHz	100%	-5 dBm/MHz	45 dBm	
246-250 GHz	100%	-5 dBm/MHz	45 dBm	
250-252 GHz (Note 3)	100%	-15 dBm/MHz	35 dBm	
252-260 GHz	100%	-5 dBm/MHz	45 dBm	

Note 1: The operating frequency range (OFR) is defined over the 10 dB reduction of the intentional transmission ("10 dB bandwidth") radiated by the equipment into the air. The unwanted emission limits apply to the frequencies outside the OFR. The measurement bandwidth for the unwanted emissions domain is 1 MHz.

Note 2: The given maximum mean e.i.r.p. spectral density is valid for averaging over the whole measurement cycle T_{meas_cycle} of the device including any T_{off} times in 1 MHz resolution bandwidth of the measuring receiver.

Note 3: Sub-band protected by the provision RR No. 5.340 [7].

Note 4: The maximum peak e.i.r.p. shall be measured/evaluated in 1 GHz bandwidth.

Additional requirements for radiodetermination systems for industry automation in shielded environments (RDI-S) to allow licence-exempt use:

1. For RDI-S, the 10 dB contiguous bandwidth shall be equal to or higher than 35 GHz;
2. The operation of RDI-S sensors is envisaged for industrial purposes only;
3. Installation and maintenance of RDI-S equipment shall be performed by professionally trained individuals only;
4. RDI-S equipment shall not be marketed to private end customers;
5. RDI-S equipment shall only be operated indoors (i.e. inside a building) or inside similarly shielded environments;
6. Installers have to ensure that the device main beam is not pointing towards windows or other weak shielded parts of the shielded environment. The direction of main radiation shall be indicated on the specific radiodetermination device;
7. Installers have to ensure that there are no unwanted obstacles in the main beam of the antenna in order to minimise unintentional reflections and scattering;
8. Slow sweeping RDI-S devices with sweep slopes smaller than 2.5 GHz/ms shall notch-out the frequency bands subject to the provision RR No. 5.340 [7] by at least additional 10 dB reduction in mean and peak power (i.e. limits in Table 10 columns B and C reduced by 10 dB);
9. The provider is required to inform the users and installers of RDI-S equipment about the installation requirements and additional special mounting instructions;
10. For RDI-S devices using an antenna gain smaller than 20 dBi, the maximum conducted peak output power shall be limited to 15 dBm.